



(19)

Europäisches Patentamt

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(11)

EP 1 101 936 A2

(12)

## EUROPEAN PATENT APPLICATION

(43) Date of publication:  
23.05.2001 Bulletin 2001/21

(51) Int Cl.7: F03D 11/04, F03D 1/06

(21) Application number: 00125115.6

(22) Date of filing: 17.11.2000

(84) Designated Contracting States:  
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
MC NL PT SE TR

Designated Extension States:  
AL LT LV MK RO SI

(30) Priority: 17.11.1999 DK 165499

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### (54) Method for mounting main components in a nacelle of a windturbine

(57) The nacelle structure of a wind turbine is provided with winches (31) and trolleys (30) for lifting and

lowering the main components of the wind turbine, such as a generator (11), gearbox (7) and wings (3),

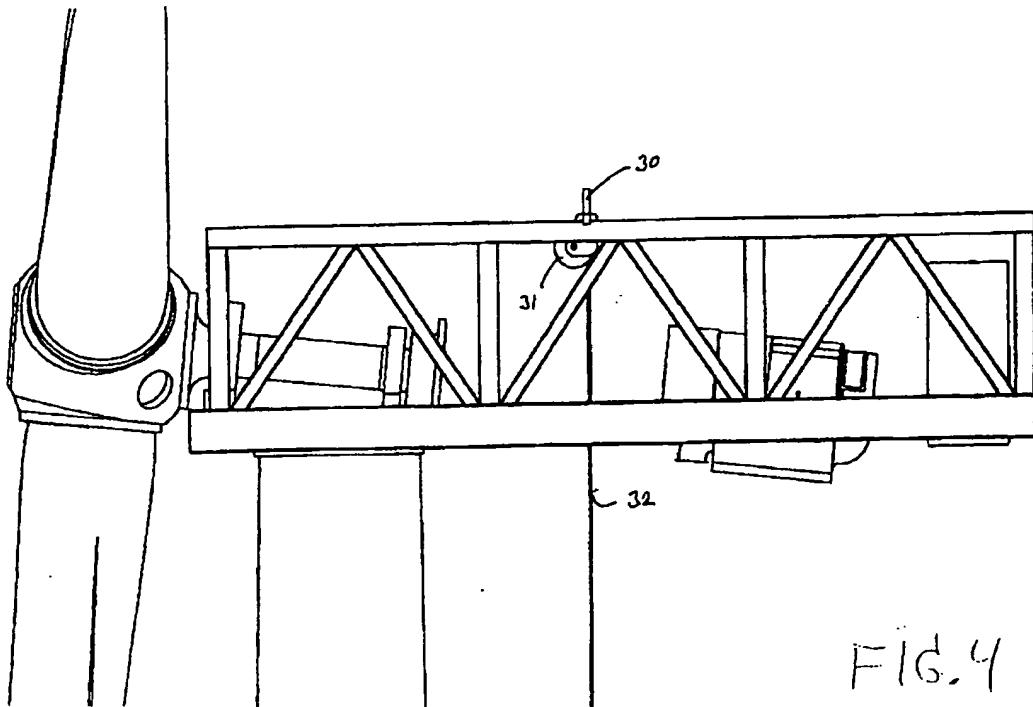


FIG. 4

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**Description**

[0001] The present invention concerns a method for mounting main components in a windmill nacelle and a nacelle for a windmill and for mounting main components such as generator and gearbox and wings, which nacelle is provided with side members with fastening means for fastening the main components to the nacelle.

[0002] The nacelle on windmills of conventional type is normally made with a welded or cast machine frame onto which the transmission and yawing system are fitted. The machine frame may be designed in different ways so that greater or lesser parts of it form a part of the construction that is to absorb the loads from the rotor. In certain constructions, the machine frame mainly consists of steel sections where the front part supports the transmission system and forms the transition to the yawing system, whereas the rear part is cantilevered without any direct support on the yawing system and which by itself carries heavy main components, especially the generator. The covering of the nacelle may, for example, be constituted by a glass fibre shell integrated with steel framework carried by the steel sections of the machine frame. In other constructions, the machine frame itself constitutes the lower part of the nacelle covering so that the further covering needed is limited to the upper part of the nacelle.

[0003] In other constructions, the machine frame is limited to a bearing part between yawing system and transmission system. Here, the other heavy main components, e.g. the generator, are carried by the nacelle covering which in this case must have sufficient strength and rigidity for ensuring a functioning suspension of the main components.

[0004] Several of the main components of the windmill are fitted in the nacelle, typically shaft/bearing arrangement, gear, generator and transformer etc.

[0005] When mounting shaft/bearing arrangement and the other main components, a method of mounting the main components on the machine frame from above is normally used. This direction of mounting is natural in the usual production process at the assembling factory, where first the bearing main components in the shape of machine frame and possibly nacelle covering are made ready, and where the main components in the mill are hoisted down on the bearing construction from above with a crane afterwards. The bearing construction is then provided with contact surfaces on the upper side of which the main components may rest when the main components have been hoisted down in place in the nacelle so that the main components unhurriedly may be fastened to the side members by means of screw bolts or in other ways while the main components are resting on the contact surfaces of the side members due to gravitational force.

[0006] A special version of this method of mounting is sometimes used by erecting very large windmills where

it may be inconvenient or impossible to lift an assembled mill top upon the tower. In such a field mounting, the method may be used that in the first place the machine frame and possible further necessary main components of the nacelle, typically shaft/bearing arrangement, are lifted upon the tower only. Then the other main components of the mill may be fitted in the machine with a crane.

[0007] The crane, which typically is the same as used for raising the windmill tower, hoists the main components from the ground and up to the required height over the nacelle, swings the main components in over the nacelle, and from there lowers the main components down on the contact surfaces of the side members. In a typical sequence where shaft/bearing arrangement is mounted together with the machine frame, gear, generator, transformer and nacelle top may be mounted piece by piece in this way.

[0008] This prior art method for mounting the main components in the windmill is connected with several drawbacks.

[0009] By field mounting of large mills on high towers, a crane with great lifting height is to be used for the whole process. Though certain main components may have much less dead load than the tower and the machine frame, normally it would be rational to use the same large crane that may lift the greatest of the loads of tower and machine frame also for lifting even the smaller main components. The requirement of a great lifting height also contributes to make the supply small and the prices high, and therefore it would not be rational to bring in a further crane for lifting the lesser loads. The prior art method for field mounting is therefore connected with the weakness that some hours are used on a large and costly crane.

[0010] It might be a more significant disadvantage by the prior art method for mounting the main components, whether it is practised in an assembling factory or during field mounting, that by possible replacement the main components in the windmill are to be lifted up from their position on the machine frame before they may be lowered down to the ground surface. In many cases, the main components are to be lifted up over an upper rim of the covering, typically several meters above the contact surfaces on the machine frame. When extra height is calculated with for the main component itself and for straps, hook, etc., the required crane height typically becomes 5-10 m higher than the height of the windmill hub. Therefore a crane with great lifting height is required also by replacement works. Even though this requirement may be combined with a requirement of large capacity measured in load in the case of the large main components, by the lesser main components it may occur that the lifting height by itself necessitates use of a large crane with the associated drawbacks in the form of small supply and high prices.

[0011] By large windmills installed at sea, the floating crane required for installing mill tower and mill top will

normally be of such size that the whole mill top may be mounted in one lift. Thus there is not much relevance in field mounting of main components. In return, the problem with replacing main components is substantially worsened compared with installation on land. In order to ensure sufficient stability at positioning and mounting or dismounting in the mill top, even by main components of moderate weight it may be necessary to make use of even very large floating cranes. The problem may be solved in a different way by using stable platforms, e.g. with barges of the jack-up type, but in return such barges usually have very small lifting capacity. All in all, the expense for replacing main components on windmills installed at sea may easily be of a size far exceeding the expense for the main components themselves.

[0012] Windmill constructions are known where a crane is built in. Such a built-in crane will normally have a lifting capacity of at least an order of magnitude less than the lifting capacity required for lifting in connection with replacing the largest main components. The reason for such a crane normally not being dimensioned for lifting large main components is the very considerable moment required if the crane is in the form of a swinging crane, e.g. of same kind as a typical lorry crane. An embodiment as swinging crane will normally be preferred as it enables lifting the part to be replaced up and out over the upper rim of the nacelle, wherefrom it may be lowered to the ground with a winch. Even by a favourable mounting position in the middle of the main components, a typical dimensioning moment for the crane for a 2 MW windmill will be of the magnitude 1000 kNm corresponding to a lift of 15 t with an arm of 6-7 m. A moment of this size substantially exceeds what normally may be mounted on a lorry, so that it is not possible to take advantage of a standard crane for the windmill. Of course it is possible to make a custom built crane with the necessary lifting capacity which may be installed in a mill top but the expenses for the crane would be very significant compared with the other expenses for the windmill.

[0013] It is the purpose of the present invention to indicate a method and a windmill nacelle relieving the said disadvantages so that installation and replacement of main components may take place without use of or with reduced requirements for external cranes.

[0014] This is achieved according to the present invention with a method of the kind mentioned in the introduction and having the features indicated in claim 1. The nacelle according to the invention has the features indicated in claim 6.

[0015] With the present invention there is thus provided a nacelle for a windmill and a method for mounting/installing main components in windmills which enable field mounting with reduced use of crane and which enables replacement of even the largest main components totally without any use of crane.

[0016] With the invention there is thus provided some kind of lifting arrangement as the nacelle is provided with

at least one winch (or tackle if the winch stands on the ground) which is arranged so that it may be disposed at such positions that each component may be placed at the right spot in or at the nacelle. This is made possible

5 as the nacelle is arranged to receive the components from below. The contact surfaces in the nacelle may face downward or upward depending on the shape of the connecting means of the main components. The contact surfaces are provided at the underside or the  
10 top side of the side members. These side members may be provided in the top or the bottom of the nacelle which is provided with an opening for introducing the main components. This opening is preferably in the bottom of the nacelle but may be in an end or side wall as components  
15 may then be hoisted up and introduced by means of a projecting arm supporting the winch/tackle, and which may be displaced or swung into the nacelle with the main components in the elevated position.

[0017] By mounting the main components from below  
20 and up into the nacelle by field mounting, and not as previously done, i.e. from above and down into the nacelle, the height required for a crane to be able to mount the windmill will only be determined by erecting the mill tower and machine frame. This will normally be a lower  
25 height than the one required by mounting the subsequent main components in the nacelle in the usual way during field mounting.

[0018] When the machine frame is mounted at first, the subsequent main components may be mounted  
30 without further use of the crane whereby this is released for other tasks. For this is only required a winch with the needed lifting ability, either mounted in the mill top or mounted on the ground and with the necessary wire or chain connection for a tackle arrangement in the mill top.  
35 In the mill top no built-in swinging crane is required for performing a mounting as described. Everything needed is a point of attack for winch or tackle.

[0019] Provided that the main components are mounted from below and up into the nacelle, either directly or by mounting them as always otherwise done, namely from above and down into the nacelle, but on elements of the machine frame which by themselves are mounted from below and up into the nacelle, by replacing  
40 the main components in the field there may be used

45 the method that the main components are lowered through the bottom of the nacelle and vertically or approximately vertically down to the ground. For this is only required a winch with the necessary lifting ability as by field mounting as described above, either mounted in the mill top or mounted on the ground and with the necessary wire or chain connection to a tackle arrangement in the mill top. Replacement of main components may thus occur without the use of a crane. No built-in swinging crane is required in the mill top for performing a lowering as described. All what is needed is a point of attack  
50 for a winch or a tackle.

[0020] In order to make the described method feasible, the nacelle has to be arranged in such a way that

the main component may be mounted from below and up on the machine frame. This may, as mentioned above, occur directly or by mounting the main components from above and down into the nacelle but on elements of the machine frame which by themselves are mounted from below and up into the nacelle.

[0021] In a nacelle according to the invention, the main components are thus retained in upward direction at the underside of the side members. This enables mounting of the main components from below instead of from above in a simple way.

[0022] By the new way of mounting main components it is also necessary to change the side members so that the main components still may be fastened to the nacelle. Therefore, it is necessary to think unconventionally and to make the side members in such a way that the new way of mounting main components becomes possible to implement. By the side members being provided with flanges extending outwards in relation to the side members it is possible to provide the flanges with undersides, where an upper side on corresponding flanges on the main components may be retained against and fastened to the undersides.

[0023] In a preferred embodiment of the nacelle according to the invention, the nacelle is characterised by the side members forming support for a trolley with winch, and that one or more of the main components are intended to be hoisted from below and up into the nacelle by wires or the like being led to the winch, that the main components are fastened at one end of the ropes or wires, and by pulling in the other end of the ropes or wires.

[0024] By fitting a trolley with winch in the nacelle it becomes possible by means of wires or the like to hoist the main components up into the nacelle after the nacelle has been mounted at the top of the windmill tower. By driving mechanisms situated on land or on a floating barge it may then be possible to hoist the main components up in the desired height independently of the real height of the windmill tower.

[0025] In a second preferred embodiment, the machine frame of the nacelle is constituted by a construction with at least an upper horizontal or approximately horizontal beam and at least one lower horizontal or approximately horizontal beam, which are mutually connected with means for absorbing shearing forces, for example a lattice work. In this preferred embodiment an upper beam may constitute a track for a trolley while the main components may be attached to a lower beam. Hereby, the particular advantages that the nacelle and the machine frame at the same time can be made with particularly large rigidity are achieved simultaneously with the tracks of the trolley being made without any influence of the main components of the machine frame which must be arranged for mounting the main components.

[0026] The invention will then be described in more detail with reference to the accompanying schematic

drawing, where:

- Fig. 1 shows a partial view, partly in section, of a prior art windmill nacelle,
- 5 Fig. 2 shows a partial view of a windmill nacelle according to the invention,
- Fig. 3 illustrates steps by a method according to the invention,
- 10 Fig. 4 a view corresponding to Fig. 2 for illustrating the nacelle during the mounting steps according to Fig. 3,
- Fig. 5 shows perspective view of the nacelle during a second step of the method according to the invention,
- 15 Fig. 6 an illustration corresponding to Fig. 3 but for illustrating other steps of the method,
- Fig. 7 a view corresponding to Fig. 4 of the nacelle during the mounting steps shown in Fig. 6, and
- 20 Fig. 8 a perspective view of the nacelle during the mounting steps shown in Fig. 6.

[0027] Figure 1 shows a windmill with a normal arrangement of the nacelle. The spinner 1 is fitted on the mill hub 2 which also carries the wing 3 that may be turned on the bearing 4. The main bearing 5 supports the main shaft 6 at the front, and at the rear the shaft is supported by the gear 7 which is fastened to the shaft with a crimp connection. The mechanical brake 8 is disposed on the fast shaft of the gear also carrying a coupling element 9 which by an intermediate piece 10 forms the connection to the generator 11. At the rear of the nacelle there are mounted meteorological instruments at the top 12 of the discharge system. The yawing bearing 13 carries the nacelle yawed by a number of yawing gears 14 the drives of which engage the toothed rim 15 of the yawing bearing. The bearing plate 16 supports the main bearing at the front and the gear at the rear and also carries the covering 17 supporting the generator. A heat exchanger 18 for the generator and an oil cooler 19 for the gear provide cooling for the most important main components. As the nacelle is upwardly closed, replacement of the main components requires that these are lifted up over the top rim of the nacelle.

[0028] Figure 2 shows a complete nacelle according to the invention. The nacelle is shown without any covering. A front main bearing 20 corresponds to the main bearing 5 in the normal embodiment. A rear main bearing 21 supports the rear part of the main shaft. A flange 22 coupling provides connection between the main shaft and the gear 23 which may easily be loosened by dismounting. In a conventional way, a fast-running coupling 24 forms connection between the gear and the generator 25. At the rear of the nacelle there is disposed a transformer 26. The machine frame itself consists of a set of lower side members 27 and a set of upper side members 28 connected with a lattice work 29. On the upper side members there is provided a trolley 30 carrying a

winch 31.

[0029] Figure 3 shows the method by partly mounting main components in the field. The volley 30 is here positioned over the place of the gear in the nacelle, and the gear 33 is hoisted in place with the winch 31 and a long wire 32.

[0030] Figure 4 shows a close-up of a nacelle during the process shown in Figure 3. The trolley 30, the winch 31 and the wire 32 have the functions described above.

[0031] Figure 5 shows a perspective illustration of the nacelle during mounting or dismantling of the generator. The trolley 30 is here disposed over the place of the generator, and the generator is under hoisting with the winch 31 and the wire 32. The gear 32 is here at its normal place.

[0032] Figure 6 shows the use of the nacelle equipment by piece by piece mounting or replacement of wings.

[0033] Figure 7 shows the arrangement in the nacelle during the process shown in Figure 6. The trolley 30 is here mounted relatively far ahead, and the wire 32 is drawn through the manhole 33 by the winch 31. A corresponding manhole 34 at the other wing is seen a little more clearly. The wire runs around the tackle 35 in the hub and may hoist the wing therefrom.

[0034] Figure 8 shows a perspective view of the nacelle during the process shown in Figure 7.

#### Claims

1. A method for mounting main components in a windmill nacelle, **characterised** in that the nacelle is disposed on the top of the mill tower at first, and that the main components are hoisted up afterwards, as they are fitted in or at the nacelle from below from an underside of the nacelle and upwards in or at the nacelle.
2. A method according to claim 1, **characterised** in that initially a windmill tower is raised, that the nacelle is subsequently mounted on a supporting surface at the top of the windmill tower, and that finally the main components, like generator, gearbox and wings, are mounted in or at the nacelle.
3. A method according to claim 1 or 2, **characterised** in that the main components are mounted by means of a winch fitted at the upper side of the nacelle or via a tackle mounted at the top side of the nacelle.
4. A method according to any preceding claim, **characterised** in that by the mounting, the main components are fastened to the underside of side members at the bottom of the nacelle.
5. A method according to any preceding claim for replacing main components, **characterised** in that

the main components during the replacing are hoisted/lowered with a winch mounted at the top side of the nacelle or via a tackle mounted at the top side of the nacelle.

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6. A nacelle for a windmill and for mounting main components like generator and gearbox and wings, the nacelle being provided with side members with fastening means for fastening the main components to the nacelle, **characterised** in that the nacelle is provided with a lifting arrangement in the form of a winch or a tackle arranged for displacing in the nacelle, that the main components may be disposed mutually at the correct position, that the side members are provided with connecting means at their underside forming abutment for corresponding connecting means on main components for retaining the main components at the side members, and that the nacelle comprises an opening through which the main components may be introduced into or at the nacelle.
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7. A nacelle according to claim 6, **characterised** in that the connecting means comprise flanges extending laterally, that the connecting means of the main components are corresponding flanges extending laterally from the main components, and that a top side of the flanges on the main components is intended for abutting on a underside of the flanges of the side members.
8. A nacelle according to claim 6, **characterised** in that the connecting means of the side members comprise flanges extending laterally, that the main components are mounted on a support comprising corresponding flanges which extend laterally from the main components, and that a top side of the flanges on the parts on which the main components are mounted are intended for abutting on an underside of the flanges of the side members.
9. A nacelle according to any of claims 6 - 8, **characterised** in that the nacelle is furnished with at least an upper horizontal or approximately horizontal beam and at least one lower horizontal or approximately horizontal beam, which are mutually connected with means for absorbing shearing forces, for example a lattice work, where the upper beam constitutes a track for a trolley supporting the winch or the tackle.
10. A nacelle according to any of claims 6 - 9, **characterised** in that the nacelle is provided with a number of tackles at its top side, and that the main components are intended to be hoisted from below and up into the nacelle by ropes, wires or the like being passed through the tackles and fastened to the main components and to a winch mounted at the

top side or the underside of the nacelle.

11. A nacelle according to any of claims 6 - 10, **characterised** in that the side members at which the main components in the nacelle are mounted are 5  
optionally situated at the underside or the top side of the nacelle.

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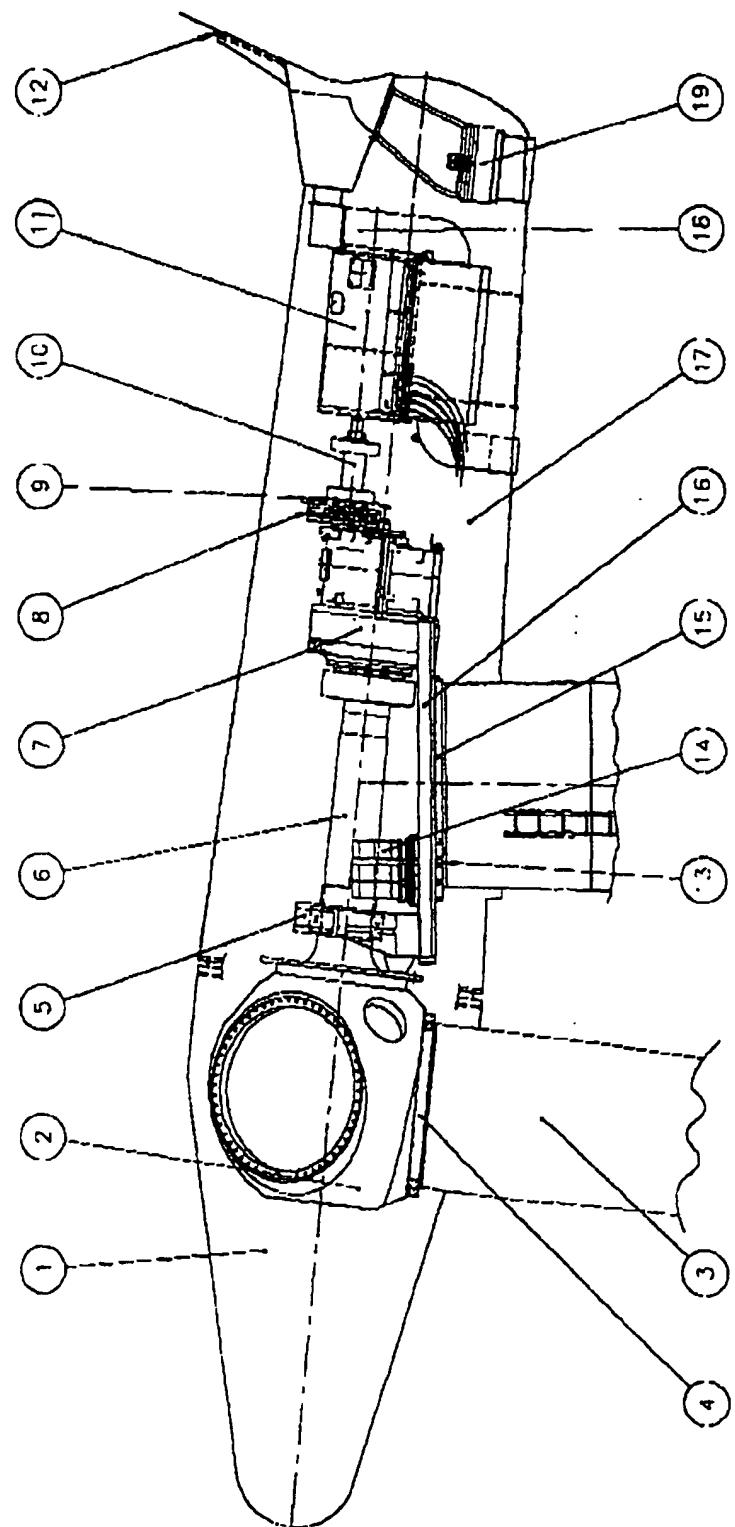


FIG. 1

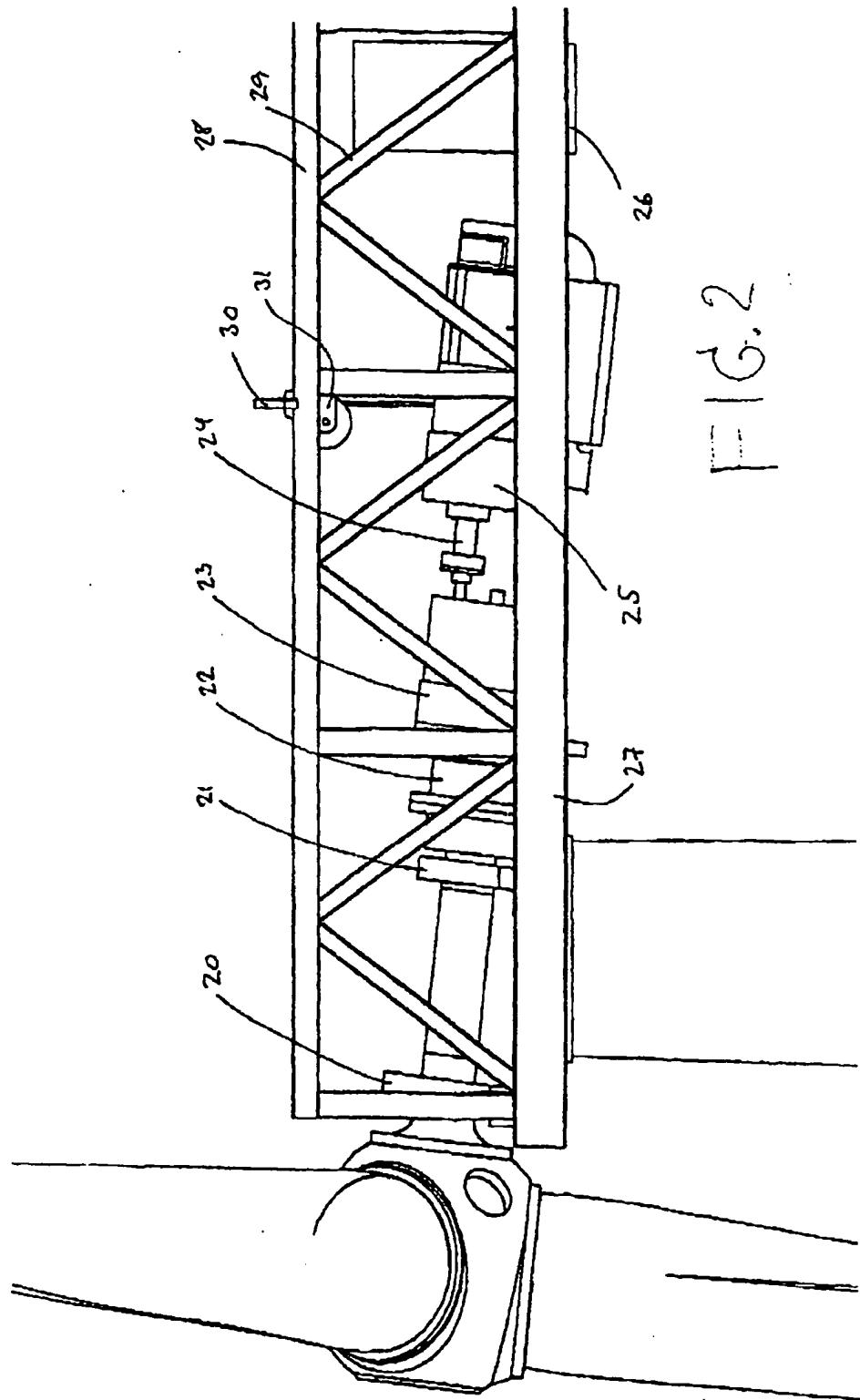


FIG. 2

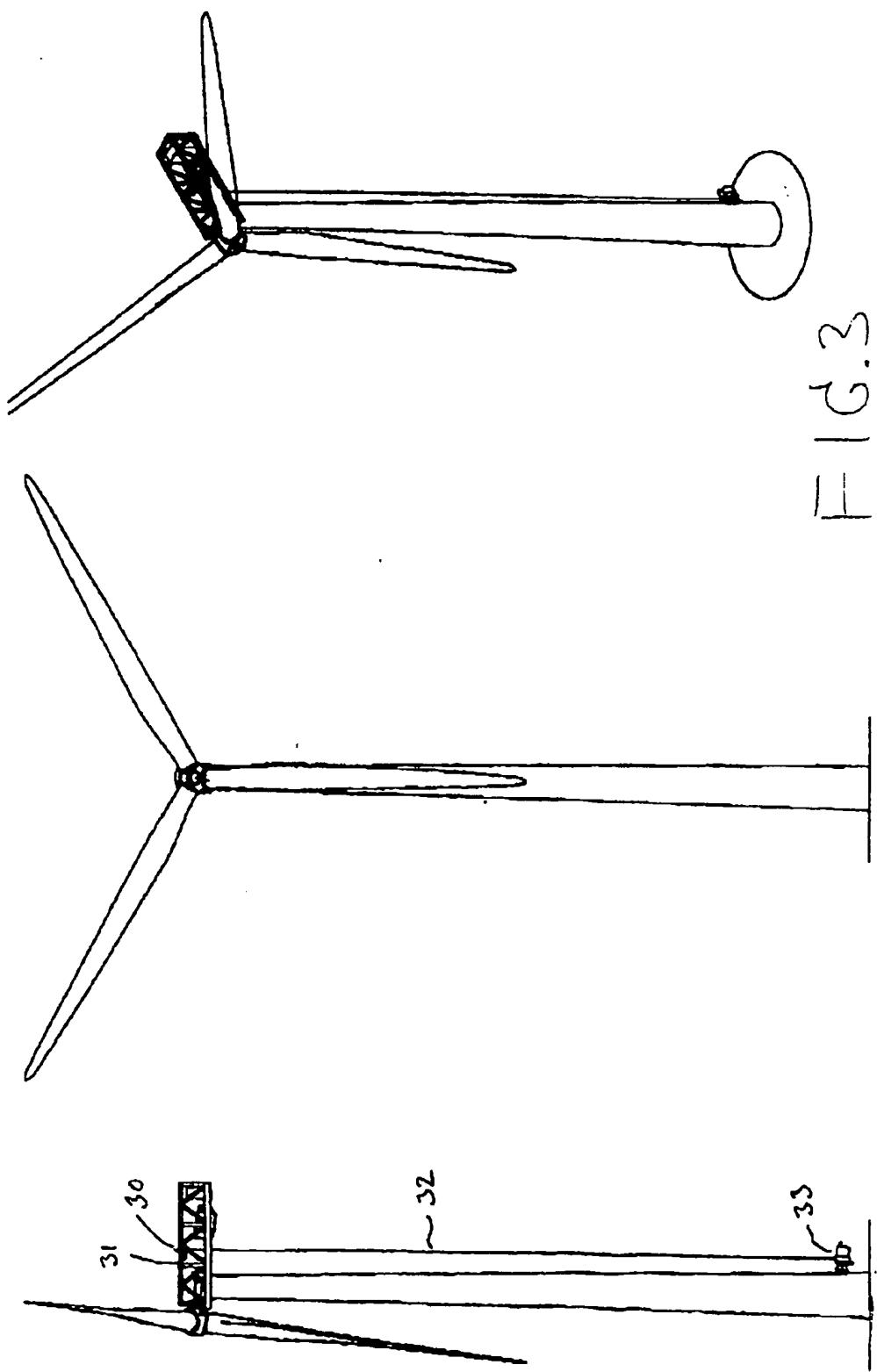


FIG. 3

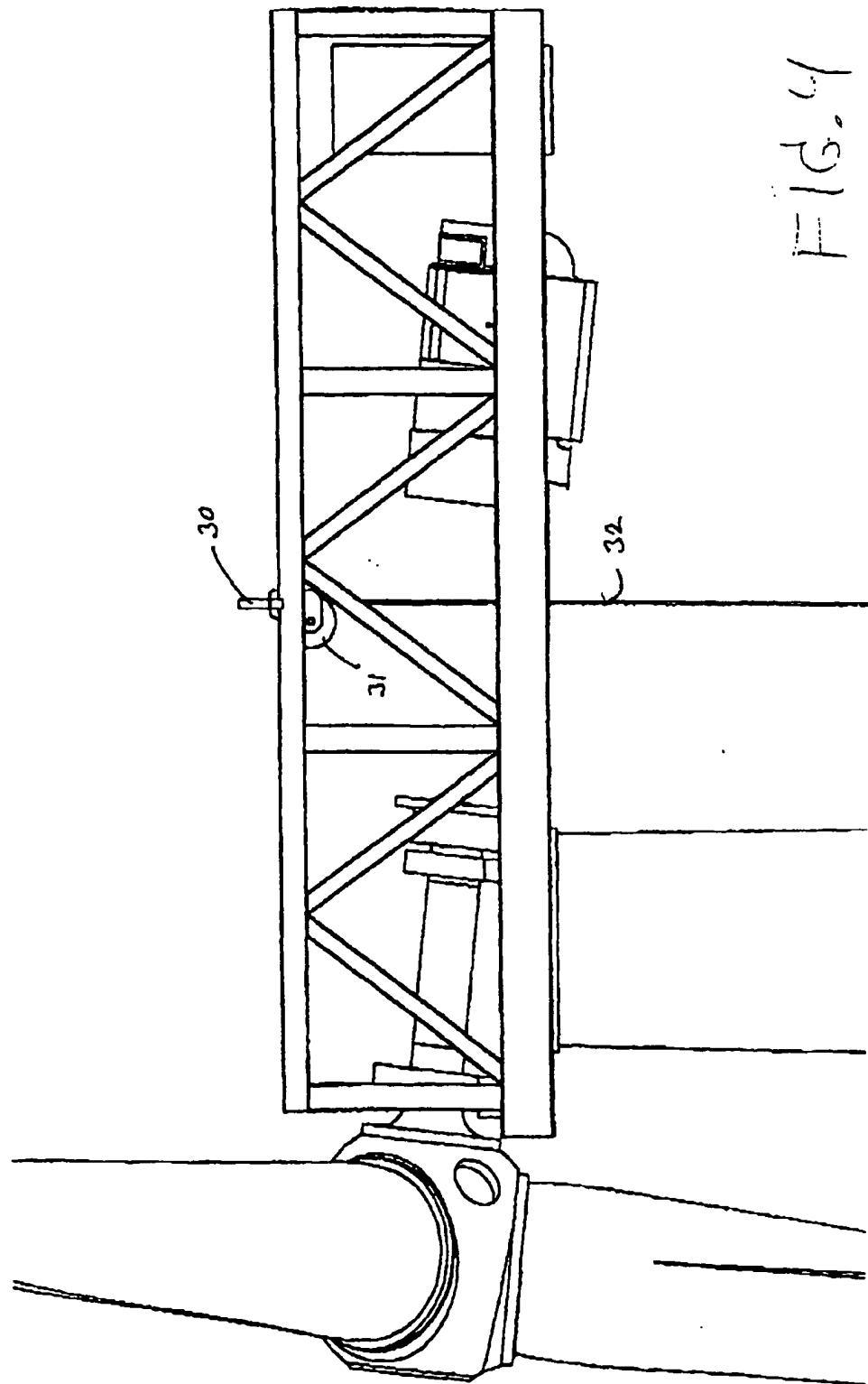


FIG. 4

FIG. 5

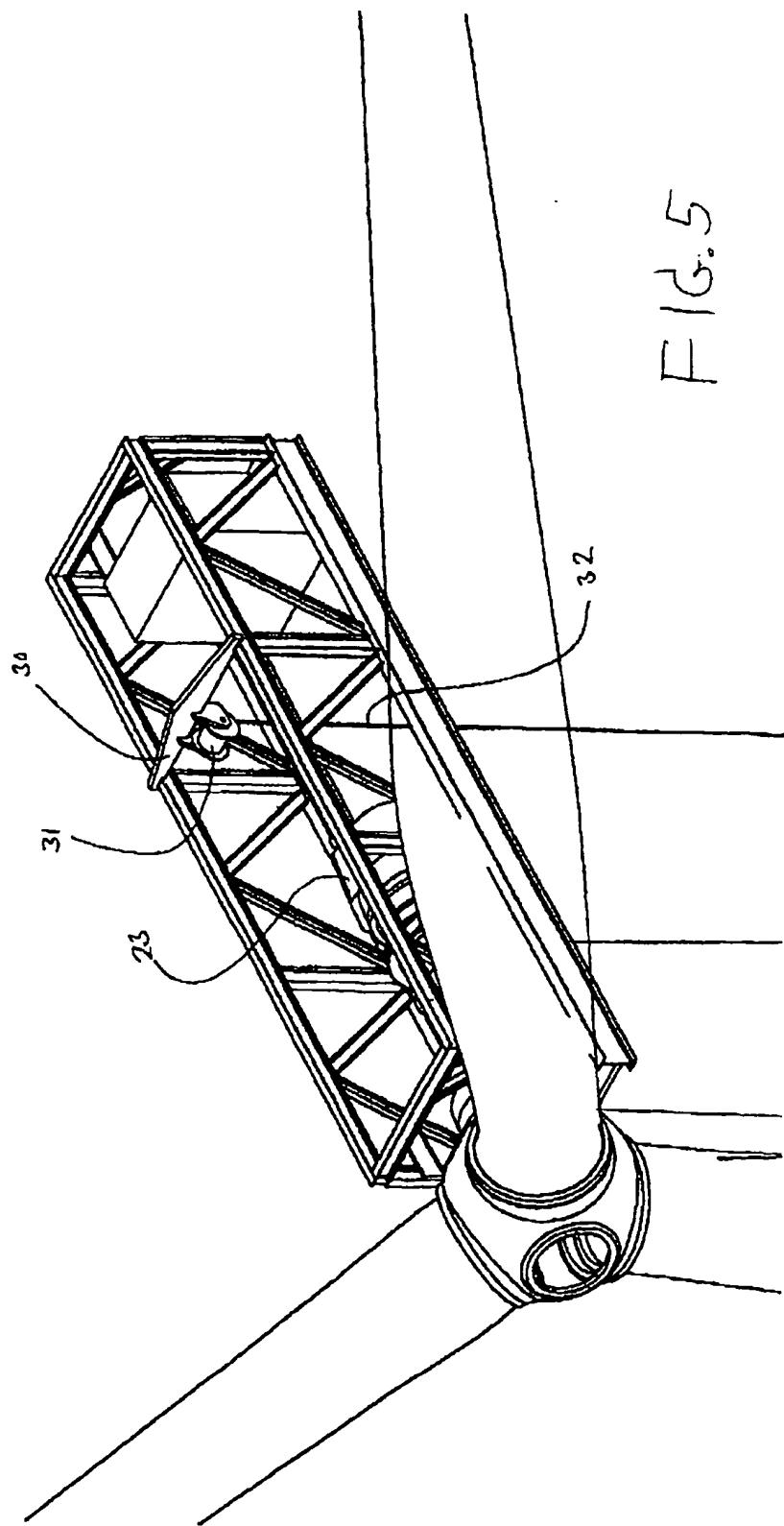


FIG. 6

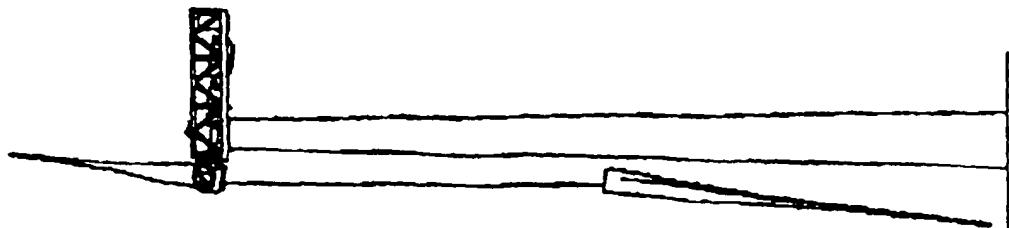
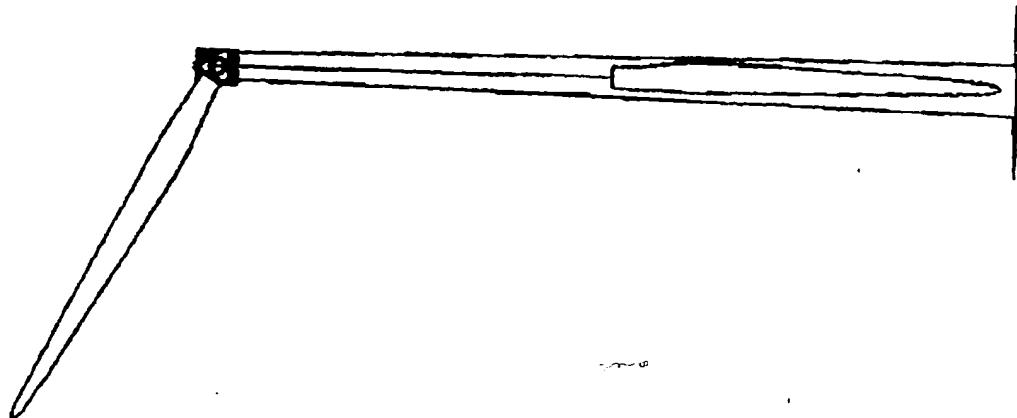
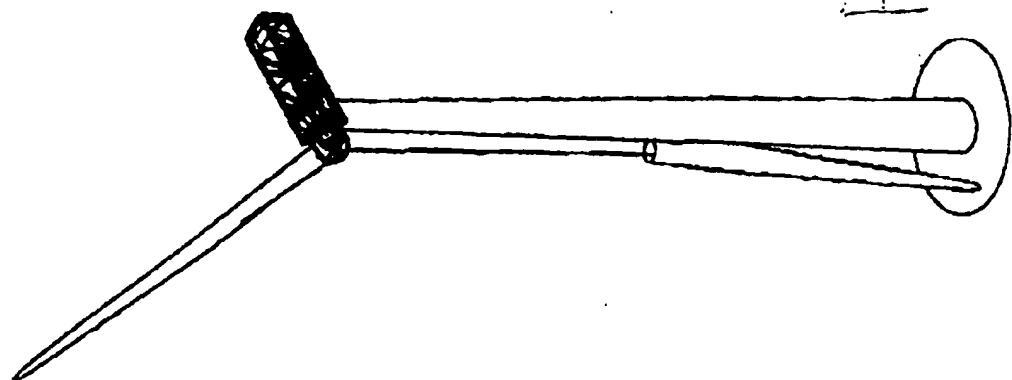


FIG. 7

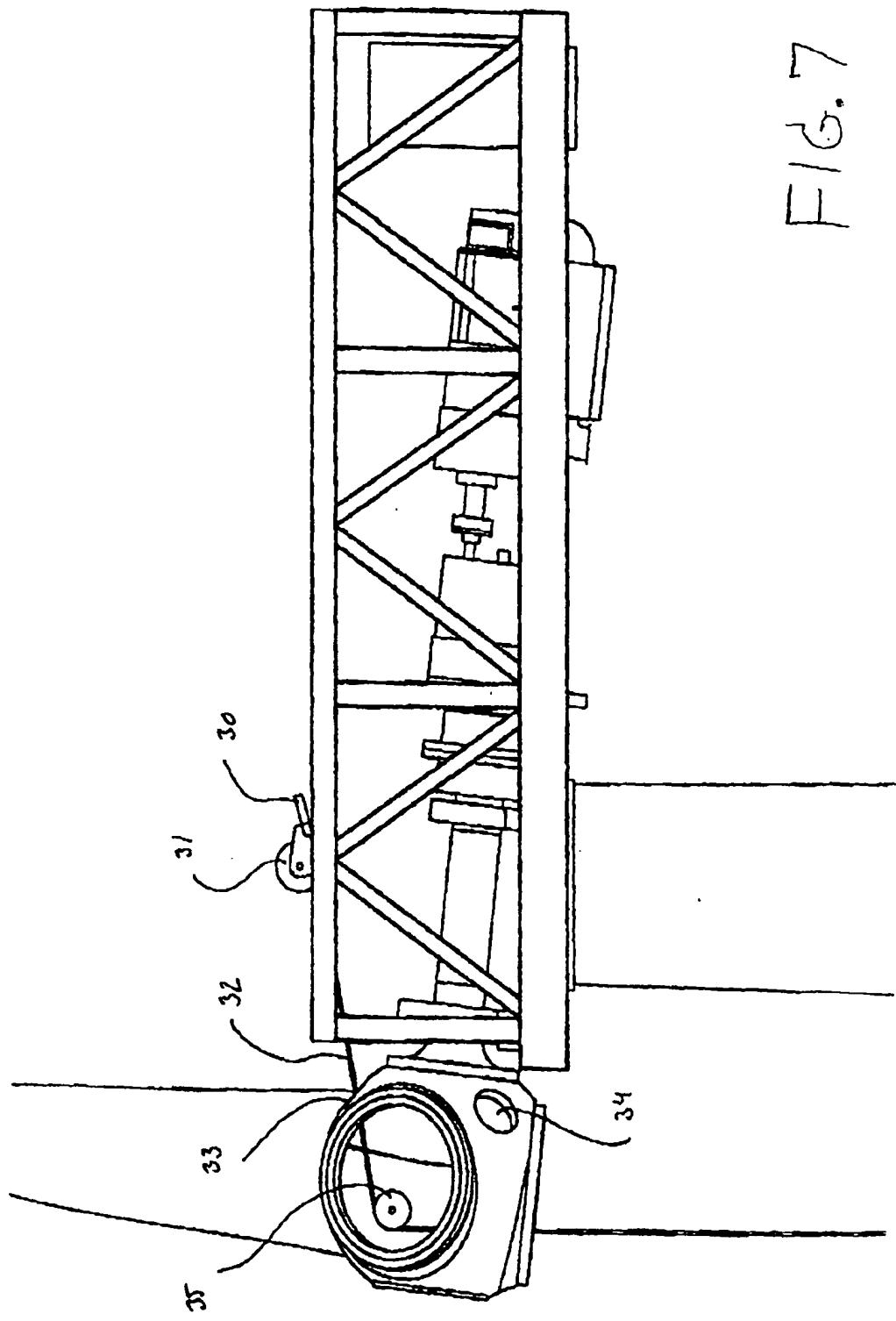


FIG. 8

